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(54) FUSION FURNACES

(71) We, SAINT-GOBAIN INDUSTRIES, a Body Corporate organised and existing under the laws of the French Republic, of 62 Boulevard Victor Hugo, 92209 Neuilly Sur Seine, France, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention has as its subject improvements in glass melting furnaces, particularly for the manufacture of plate glass.

Known furnaces of this type essentially comprise two parts:

a hot upstream zone for fusion and refining to which the initial materials forming the glass composition are introduced to be melted by means of heating devices, such as burners; and

a cooler downstream zone for conditioning the glass in which the glass is brought to an appropriate temperature to be removed for subsequent manufacturing operations. This zone for homogenising the temperature is known as the conditioning zone.

The convection currents which are generated in the furnace because of temperature differences, and the withdrawal of the glass from the furnace cause a more or less pronounced stirring of the glass. In particular, in the conditioning zone there is established a current which travels downstream which occupies approximately the upper third of the height of the bath of glass and a return current below which occupies the lower two thirds of this height.

It is known to introduce across the conditioning zone at appropriate points mechanical or thermal barriers which may float or be fixed which extend across substantially all the width of the furnace to separate two zones of the bath of glass especially to stop the flow of glass at the surface and lift the cooler glass. It is also known to cause the glass currents to pass through openings provided in the depth of the bath and also to cause mixing of the downstream current by means of agitators, which current is separated mechanically from the return current by a wall to avoid mixing of the two currents of glass. This process is difficult to carry out by reason of the major corrosion to which is subjected the wall which separates the upstream and downstream current and the difficulties in carrying out repairs inside a bath of molten glass.

It has now been found that it is possible to improve the quality of the glass by causing reversal of certain predetermined streams of the forward current to cause them to be absorbed by the return current below and direct them towards the zone of melting by the action of a barrier which only acts in a central part of the width of the furnace, in such a manner as to allow free passage of the side streams over a width sufficient to supply the desired rate of discharge of glass from the furnace.

According to one aspect of the invention, there is provided a process for producing molten glass in a furnace in which the glass constituents are fused in a fusion section and the fused glass flows through an adjacent conditioning zone, a downstream current of glass adjacent the upper surface of the glass flowing in the direction from the fusion section to the conditioning section and a return current of glass below the downstream current flowing in the reverse direction, a central part of the downstream current being diverted by a barrier so that it is taken up by the return current and returned towards the fusion zone, and the side parts of the downstream current adjacent the central part being allowed to continue without diversion, the barrier

comprising at least one suspended element extending into the molten glass when the glass is at its normal level in the furnace.

According to another aspect of the invention, there is provided a fusion furnace for producing molten glass having a fusion zone and a conditioning zone, the furnace being provided with a barrier arranged to divert a central part of an upper downstream current of glass so that it is taken up into a return current of glass below the downstream current, the side parts of the downstream current adjacent the central part being allowed to continue without diversion, the barrier comprising at least one suspended element extending into the molten glass when the glass is at its normal level in the furnace.

The position of the barrier in the direction of the current of glass is significant. It is possible, in fact, that crystalline glass particles may form below the barrier in contact with colder elements and it is desirable that the temperature of the bath downstream should be sufficient for the crystalline particles to have the time to remelt completely in the mass of glass which surrounds them before leaving the furnace.

On the other hand the viscosity of the glass adjacent the barrier can play an important role. In order that the hydrodynamic action of this barrier will have the maximum effect, this viscosity should not exceed a value of $10^{2.5}$ poises.

The efficiency of the barrier is thus particularly good when the temperature of the glass is not substantially less than 1300°C for the compositions which are normally used in industrial glass. It can then be placed not far from the hot fusion zone; however this is difficult to realise by reason of the high temperatures which prevail in this part of the bath.

The barrier is placed in the middle part of the width of the furnace, in principle on its axis of symmetry, but the best position has to be determined experimentally. In order to avoid any indirect action of the lateral streams of the downstream current or in the return current, the barrier is preferably formed of elements suspended by means of members traversing the furnace vault; the length of the barrier across the furnace will depend on the position in the furnace and will correspond to the width of the stream of which it is desired to divert the flow; in a preferred embodiment of the invention it has a width from $\frac{1}{4}$ to $\frac{2}{3}$ of that of the bath, preferably between $\frac{1}{2}$ and $\frac{1}{3}$.

The depth and possibly the temperature of the barrier may be controlled in such a way as to cause reversal of the desired stream of the forward current at right angles to the barrier elements and its take up by the return current; the immersion required is from 1/5 and 1/2 of the height of the glass in the bath. The barrier may be deeper in the middle part than at the ends and may possess, seen across the furnace, a lower profile which is convex.

Control of the process is facilitated if the barrier is formed of distinct elements acting at the same time as a discontinuous obstacle and by the thermal action on the mass of glass which surrounds them, it is then possible to choose their number and control their position and/or their temperature independently in order to obtain the best efficiency.

Advantageously these elements are formed by refrigerated tubes having the form of juxtaposed orientable loops.

It is possible further, by causing rotation of the elements to superpose a mixing action on the diverting effect for the streams of glass.

This supplementary mixing effect may be advantageous when the furnace is working at outputs which are close to maximum capacity. It may also reduce the time for the fabrication of coloured glass during passage from one colour to another and it may assist very efficiently control of heterogeneity which may be produced in the furnace when there exist excessive faults of homogeneity in the compositions of the starting materials.

Embodiments of the invention will be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a schematic plan view of a fusion furnace with a masonry barrier,

Figure 2 is a schematic vertical section of the fusion furnace of Figure 1,

Figure 3 shows the barrier of figures 1 and 2 suspended from a furnace vault,

Figure 4 shows a barrier of a furnace in accordance with an embodiment of the invention formed by a cooled serpentine tube,

Figure 5 shows a barrier formed of separated elements,

Figure 6 shows in plan a barrier of inclined separated elements,

Figure 7 shows a barrier formed by bubbles produced by a so-called bubbler,

Figure 8 shows in perspective a series of rotary agitators arranged in line and juxtaposed with an angular difference of phase,

Figure 9 shows schematically the arrangement of the agitators of Figure 8 in the vault of the furnace,

Figure 10 shows a device for mounting and driving the agitators of Figures 8 and 9.

The fusion furnace of Figure 1 is provided with two principal zones: fusion

zone 1 and conditioning zone 2.

The charging to the furnace with starting materials takes place at 3 and discharge of glass from the bath of molten glass in the furnace by the canal 4.

A barrier 5 is arranged in the furnace in the central stream of the surface downstream current. It occupies about 2/5 of the width of the bath so that the side streams of the downstream current 6 may follow an uninterrupted path towards the canal 4 where discharge is effected.

As shown in Figure 2 the barrier 5 extends into the mass of fused glass to the approximate upper limit of the return current 7.

Figure 3 shows in transverse section a masonry barrier 8, which may be formed instead by a plurality of elements, (not shown) held by the holders 9, which are cooled by a system of water jackets 10 to prevent them corroding at the high temperature which prevails in the atmosphere of the furnace.

The barrier shown in Figure 4 is a suspended serpentine tube 11 formed of a stainless steel tube wound in a helix and in which there is maintained a circulation of water or any other cooling fluid.

This serpentine tube is immersed in the upper part of the glass bath containing the downstream current. Its action is to increase in its neighbourhood the viscosity of the glass in such a manner that the streams of the downstream current which reach the colder zone are directed towards the lower part of the bath to be taken up by the return current.

Figures 5 and 6 show a discontinuous barrier formed of an assembly of metal tubes 12 which are cooled by circulation of water arranged in the form of loops 13. These loops act on the glass mainly by their thermal action. Each cools in its plane a certain mass of glass which overlaps that cooled by the adjacent loop, to form a quasi continuous barrier.

Each loop is individually adjustable in orientation; it may thus receive, with respect to a transverse plane of the furnace, an inclination which may vary from one loop to another.

The barrier thus acquires an effective thickness greater than if the loops were all in the same plane and acts in this manner as a series of shutters of which the actions overlap.

The arrows of Figure 6 show how the side streams 14 of the downstream current follow their trajectory to feed the discharge whereas the streams 15 which impinge against the barrier are subjected to a reversal which causes their absorption by the return current below.

The loops are also adjustable in height. This allows the barrier to be given the most appropriate shape. In particular the loops situated towards the ends of the barrier may penetrate less deeply than the central loops into the mass of molten glass. Because of this the barrier acts more deeply in the middle region of the furnace and its action at the ends is weaker and the lower extremity of the barrier transverse to the flow of glass is convex.

Figure 7 shows a barrier which is an essentially thermal barrier formed by the bubbler 16 suspended across the furnace vault.

The technique of using a bubbler for homogenisation of a mass of fused glass is itself known.

It consists, starting from a tube placed generally in the neighbourhood of the bottom of the furnace, of blowing into the glass mass a current of bubbles which cause a mixing of the glass which they traverse.

In the process according to this embodiment each tube for feeding air or gas emitting the bubbles extends approximately to the limit of the downstream current and return current, the emission of the bubbles taking place in a width equal to the width of the desired barrier zone.

The rate of emission of bubbles should be fairly high to cause a reversal of the downcurrent in the barrier zone and its take up by the return current which for its part is not effected by this obstacle.

The process is especially advantageous for manufacture of glass in fusion furnaces working at the capacity limit. In this case the hydrodynamic regime which is generated in the bath following the geometry of the bath, the rate of discharge and the convection currents of thermal origin may rapidly depart from the optimum regime giving the best quality of glass. It may then be necessary to correct certain of the central streams of the down current and make it necessary to modify their path by interposition of a barrier to reestablish a more balanced regime which makes itself apparent in the greater homogeneity of the glass produced.

From this point of view, a discontinuous barrier of elements which are individually adjustable in height, temperature and direction, allows rapid determination by empirical trials of the most advantageous arrangement.

The agitators 17 shown in Figure 8 are formed by steel tubes fed with water by rotary heads which are not shown. They have approximately the form of a figure of eight. This shape has proved to be particularly effective. However they may also be formed by rectangular loops or any other shape.

The agitators entrain with their movement a certain quantity of glass of which the viscosity is increased by the cooling effect.

The down current flows about the agitators and they thus play a double role as a barrier and for mixing. These phenomena are increased when their speed of rotation is increased.

The number of agitators is a function of the width of the barrier to be established. Their speed of rotation may vary from 0 to a maximum speed at which appears enclosure of bubbles or cavitation phenomena.

The speed of rotation of the loops may be, by way of about 10 rotations per minute corresponding to a peripheral linear speed in the range 200-400 m/h, preferably 300 m/h.

The average thermal exchange by the agitator with the mass of glass may be from 50 to 100 th/h, preferably 75 th/h, which represents a feed of cooling water of at least 25 litres per minute, preferably 60 litres per minute, for an agitator diameter of 0.25 metres to 0.30 metres.

The direction of rotation of the agitators may be chosen to obtain the following effects:

1. Direction of the glass towards the centre of the bath (axis of the furnace). In this case, in each half of the furnace the agitators have the same direction of rotation, the trajectory of the edge of the agitator on the upstream side of the barrier being directed towards the furnace axis.

This embodiment is generally the most advantageous and allows an intensive effect for the barrier and for mixing.

2. Directed away from the axis of the furnace. In this case, the direction of rotation of the agitators is reversed in comparison to the preceding case.

3. Mixing effect by pairs of agitators. Each agitator then turns in the reverse direction to that of the neighbouring agitator (Fig. 9).

It is also possible to provide combinations of rectangular loops which are fixed with rotary agitators. In particular the barrier may comprise rotary agitators in its middle part and fixed rectangular loops at the ends.

Figure 8 shows a series of agitators arranged in line and rotating in the same direction with an angular separation of phase of 90°.

The interval between two agitators should be such that the zone of action of each of them overlaps at least slightly the zone of action of the neighbouring agitator. A figure of eight shape of the loops favours this result.

Figure 9 shows a half vault 18 of a fusion furnace and the position of the agitators 17 with respect to this vault.

The blades are angularly separated by 90° and their zones of action overlap.

The upper extremity of the blades is the limit of the level of glass 44.

Their lower extremity should preferably be not lower than the neutral surface separating the down flow and return current so as not to exercise mixing action on the return current.

Figure 10 shows an arrangement for mounting and driving the agitators. An agitator 17 is mounted on a shaft 48 held by two bearings 19. These bearings are mounted on a support member 20, held by hooks 21 and projections 22 to a beam 23 parallel to the longitudinal axis of an aperture 24 in the furnace vault. The shaft 18 has a conical toothed wheel 25 driven by a gear wheel 26 which is driven by a motor 27 through a shaft 28. To allow the angle of phase of the agitator to be adjusted the gear 26 may be disengaged from the gear 25 by rotation of shaft 28 about the axis 29 by means of a device which is not shown. All the assembly formed by the agitator, its shaft and support 20 may be lifted by suitable tackle. The refractory obturation pieces 30 and 31 ensure obturation of the hole 24. The upper extremity of the blade of the agitator 17 is flush with the surface of the glass bath 32. The design of the barrier, that is to say the number and speed of the agitators and their depth of immersion depends on the characteristics of the furnace and the composition of the glass, and also the exact effect desired.

WHAT WE CLAIM IS:—

1. Process for producing molten glass in a furnace in which the glass constituents are fused in a fusion section and the fused glass flows through an adjacent conditioning zone, a downstream current of glass adjacent the upper surface of the glass flowing in the direction from the fusion section to the conditioning section and a return current of glass below the downstream current flowing in the reverse direction, a central part of the downstream current being diverted by a barrier so that it is taken up by the return current and returned towards the fusion zone, and the side parts of the downstream current adjacent the central part being allowed to continue without diversion, the barrier comprising at least one suspended element extending into the upper downstream current of glass when the glass is at its normal level in the furnace.

2. A process according to Claim 1, in which the molten glass is mixed in the zone in which diversion takes place.

3. A process according to Claim 1 or Claim 2, in which the streams of glass upstream of the barrier are directed towards the central part of the furnace by agitation, the barrier being in the form of an agitator.

4. A process according to Claim 1 or Claim 2, in which the glass is separated from the central part of the furnace towards the side parts by agitation, the barrier being in the form of an agitator.

5. A process according to either of Claims 3 and 4, in which the glass is cooled in the diversion zone by removal of from 50 to 100 th/h, preferably 75 th/h, from a cross-section of the flow of glass from 0.25 to 0.30 metres wide.

6. A process for producing molten glass, substantially as hereinbefore described.

7. A fusion furnace for producing molten glass having a fusion zone and a conditioning zone, the furnace being provided with a barrier arranged to divert a central part of an upper downstream current of glass so that it is taken up into a return current of glass below the downstream current, the side parts of the downstream current adjacent the central part being allowed to continue without diversion, the barrier comprising at least one suspended element extending into the upper downstream current of glass when the glass is at its normal level in the furnace.

8. A furnace according to Claim 7, in which the barrier extends across the middle part of the furnace transverse to the direction of flow, its effective length perpendicular to the direction of flowing being from $\frac{1}{4}$ to $\frac{2}{3}$ of the width of the flow of glass and its immersed depth being from 1/5 to 1/2 of the depth of the glass.

9. A furnace according to Claim 8, in which the length of the barrier perpendicular to the flow is from $\frac{1}{2}$ and $\frac{1}{3}$ of the width of the flow of glass and the immersed depth of the barrier is approximately $\frac{1}{3}$ of the depth of the glass.

10. A furnace according to any one of Claims 7 to 9 in which the lower extremity of the barrier transverse to the flow of glass is convex.

11. A furnace according to any one of Claims 7 to 10, in which the barrier is discontinuous and composed of distinct elements.

12. A furnace according to any one of Claims 7 to 10, in which the barrier comprises a tube arranged to be fed with fluid, the tube being pierced with openings allowing a liberation of fluid in the form of bubbles across a width perpendicular to the flow substantially equal to that of the barrier.

13. A furnace according to Claim 11, wherein the barrier is formed by a plurality of tubes containing a cooling fluid.

14. A furnace according to Claim 13, in which the barrier is formed by juxtaposed cooling tubular elements in the form of loops, these elements being individually controllable in temperature and in orientation and height relative to the flow of glass.

15. A furnace according to Claim 14, in which the loops are rotatable to agitate the glass.

16. A furnace according to Claim 15, in which the loops are formed of cooling tubes having the shape of a figure of eight.

17. A furnace according to Claim 15 or 16, in which the planes of the figures of eight may be angularly phase separated with respect to the planes of adjacent loops.

18. A furnace according to any one of Claims 15 to 17, in which different groups of loops are drivable in opposite directions of rotation.

19. A furnace according to Claim 18, in which the groups of loops arranged on opposite sides of the central part of the flow have opposite directions of rotation to direct the streams of glass upstream of the barrier towards the central part of the furnace.

20. A furnace according to Claim 18, in which the direction of rotation of the loops tend to separate the glass from the central part of the furnace towards the side parts.

21. A furnace according to any one of Claims 13 to 15, in which the barrier comprises rotary loops in its middle part and fixed rectangular loops at its ends.

22. A furnace according to any one of Claims 13 to 21, when appendant to Claim 10, wherein the loops situated towards the ends of the barrier penetrate less deeply than the central loops into the mass of glass.

23. A furnace according to any one of Claims 14 to 22, in which the peripheral speed of the rotatable loops is from 200 to 400 metres per hour.

24. A furnace according to any one of Claims 15 to 23, in which the rotatable loops are each mounted on a vertical shaft connected to a transverse transmission shaft to transmit power thereto from a motor, the transmission shaft being disengageable from the vertical shaft to allow alteration of the angular position of rotatable loop.

25. A furnace according to Claim 24, in which the transmission shaft is mounted to pivot on a vertical support, and provided with a conical gear wheel meshing with a conical gear wheel on the vertical shaft.

26. A fusion furnace, substantially as hereinbefore described with reference to Figures 1 to 4; Figures 1, 2, 3, 5 and 6; Figure 7; or Figures 8, 9 and 10 of the accompanying drawings.

27. Glass, when produced by a method according to any one of Claims 1 to 6 or by means of a furnace according to any one of Claims 7 to 26.

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5 SHEETS *This drawing is a reproduction of the Original on a reduced scale.*
SHEET 1

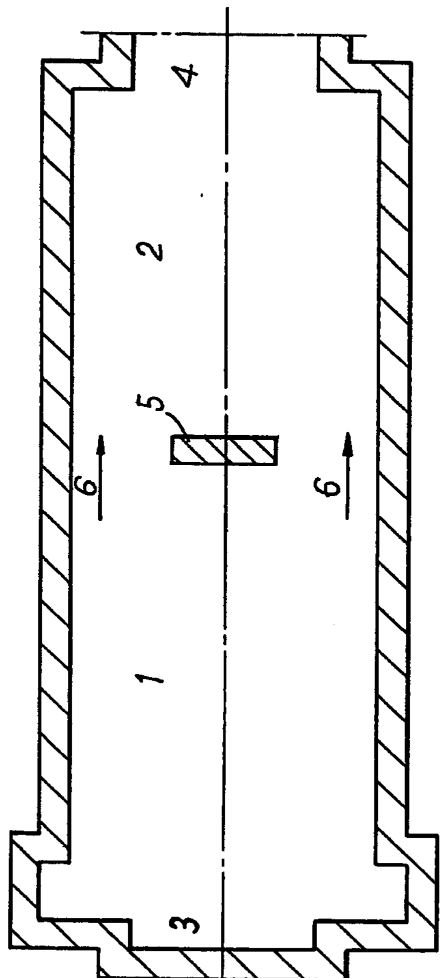


FIG. 1

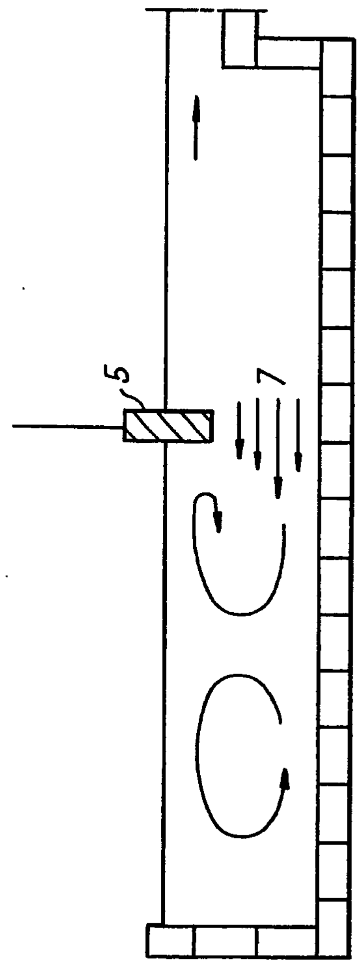


FIG. 2

FIG. 3

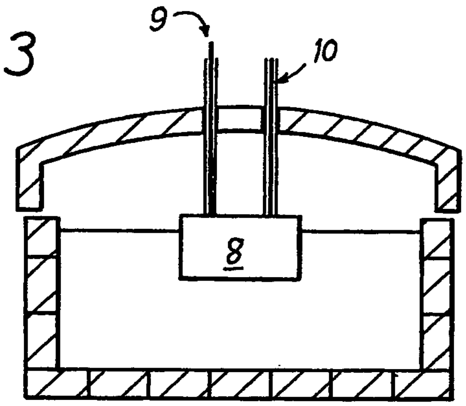
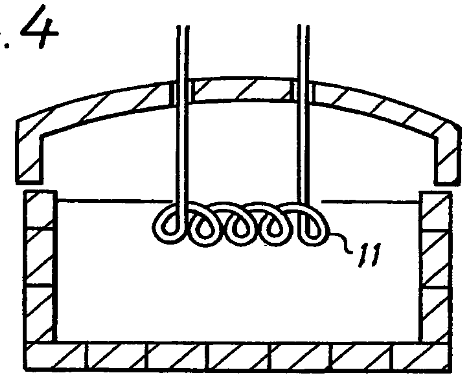


FIG. 4



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5 SHEETS This drawing is a reproduction of the Original on a reduced scale.
SHEET 3

FIG. 5

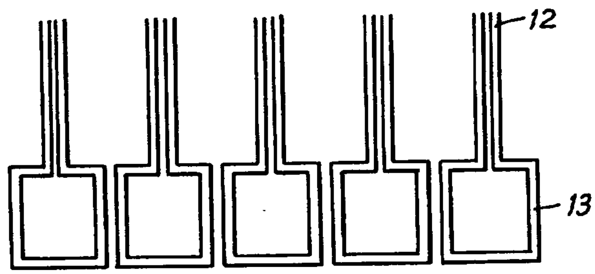

FIG. 6

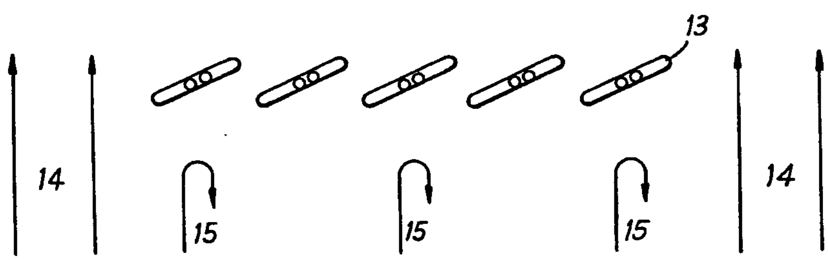

FIG. 7

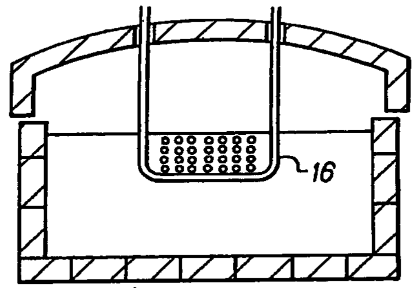

FIG. 8

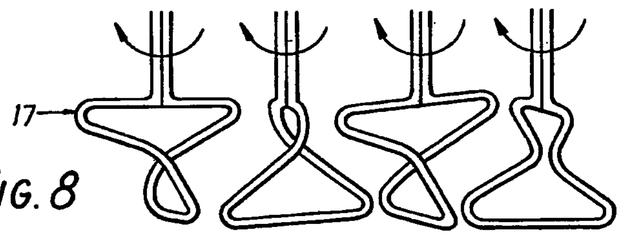

FIG. 9

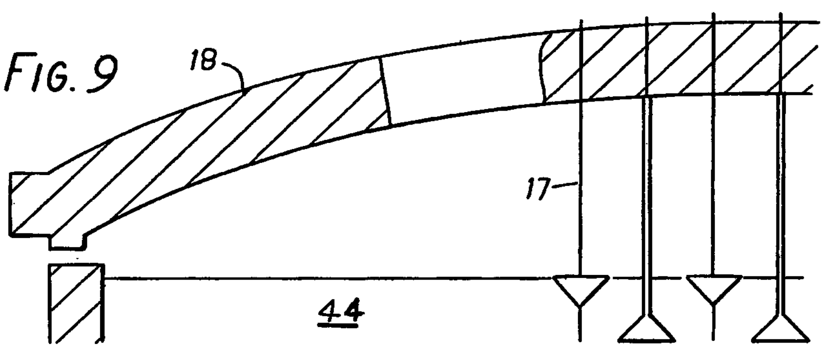

FIG. 10